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Biometric comparison of *Nemipterus japonicus* (Bloch) populations along the east coast of India

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Abstract. Morphometric comparison of the samples of *Nemipterus japonicus* populations from four different localities on the east coast of India is made. Analysis of covariance of morphometric characters reveals significance at 1% level for three characters. Character by character comparison of the means of locality-samples shows that there is clinal gradation in maxillary length (south to north) and pectoral length (north to south). The distance function $(D)^2$ analysis shows that Kakinada is the farthest removed from other localities, and Visakhapatnam and Madras samples are nearer to each other. Paradeep sample occupied an intermediate position among the locality-samples. It is concluded that all *Nemipterus japonicus* populations along the east coast of India are from a single genetic population, with restricted and localized movements confined to the areas where they are caught. The observed distinctness of Kakinada sample appears to be due to phenotypic variation under the influence of low salinity.

Keywords. Distance function; analysis of covariance; biometric comparison; locality-samples; *Nemipterus japonicus*.

1. Introduction

The Japanese threadfin bream, *Nemipterus japonicus* (Bloch), the most common of the eight species of the genus recorded from Indian waters, forms an important fishery among the demersal catches landed along the Indian coast. The species contributed to about 13% of the total trawl catches landed at Visakhapatnam Fishing Harbour during July 1977-June 1980 (Rao 1981).

The biometric features of *N. japonicus* caught off Porto Novo on the east coast of India were studied by Selva Kumar (1971) and Nammalwar (1973). Hsu and Liu (1977) compared morphometric characters of samples of *N. virgatus* obtained from the waters off Northern Sunda, East China Sea, Taiwan Straits, South China Sea and the Gulf of Tonkin. No comparison of *N. japonicus* populations from different localities has been made hitherto. The present comparison of *N. japonicus* was made with a view to judge the homogeneity or otherwise of the populations based on the samples obtained from Paradeep, Visakhapatnam, Kakinada and Madras on the east coast of India (figure 1).

2. Material and methods

All the samples were drawn randomly from the landings of small mechanised fishing boats equipped with trawl nets (cod-end mesh size ~ 22 mm). The samples were preserved in 5% neutral formalin for about a fortnight before measurements were taken. Body dimensions of 40 specimens each from four localities were taken for statistical analysis.

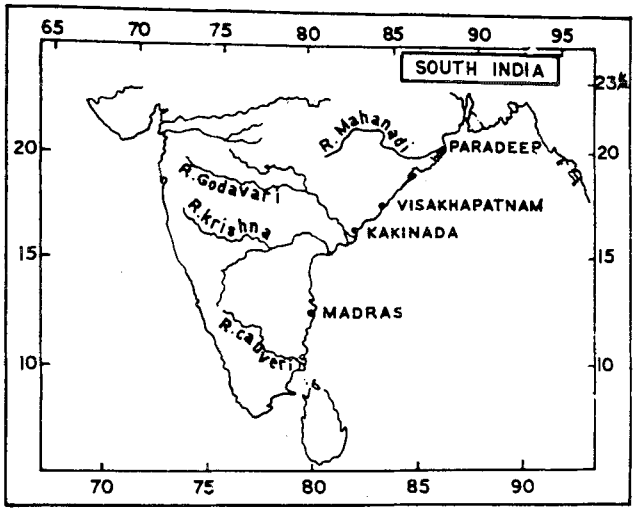

Figure 1. Sampling localities.

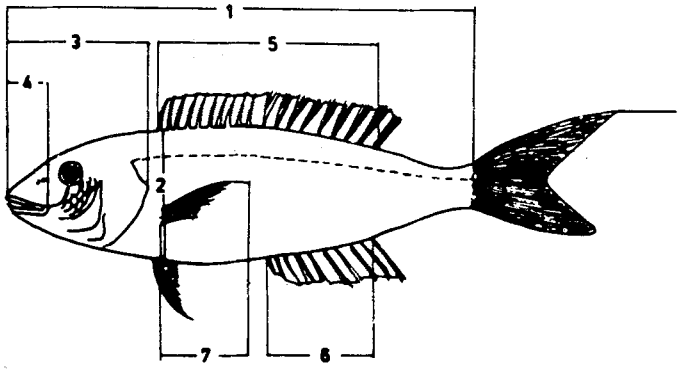

Figure 2. Schematic diagram of *Nemipterus japonicus* showing morphometric measurements. **1.** Standard length **2.** Height of the body **3.** Head length **4.** Maxilla length **5.** Length of dorsal base **6.** Length of anal base **7.** Pectoral length.

The morphometric characters selected were (i) standard length (ii) height of the body (iii) head length (iv) maxilla length (v) length of dorsal base (vi) length of anal base and (vii) pectoral length as shown in figure 2. Standard length was taken as the independent variable (X_0) and all other characters as dependent variables (X_1 ..... X_6). Height of the body, head length and pectoral length were measured following Royce (1964). The measurements made to the nearest millimeter using a pair of fine dividers were taken on the left side of the body along a straight line. The computations were made using an IBM 1130 electronic computer.

3. Physical features of localities

The localities from where samples were collected are shown in figure 1.

Paradeep: (23° 30′ N 86° 20′ E) situated at the confluence point of the river Mahanadi. The discharge of the river water has its influence on the salinity of the seawater.

Visakhapatnam: (17° 42′ N 83° 20′ E) The coast is shingly in nature, interspersed by wide stretches of sandy areas. There is no large scale freshwater influx into the sea.

Kakinada: (16° 57′ N 82° 15′ E) The northern-most distributary of the river Godavari enters into the region bringing about great changes in the salinity of seawater over a wide area.

Madras : (13°04′ N 80°17′ E) The locality is an open coastline with sandy beach. There are no large rivers entering the sea.

4. Computations

4.1 *Analysis of covariance*

The regression coefficients (*b* values) of the body characters in relation to standard length, of the samples collected from different localities, are shown in table 1. The *F*-values along with the error mean square values are also given in table 1.

4.2 *Character by character comparison of the means of the samples*

The graphical method of Hubbs and Hubbs (1953) for character by character comparison on the basis of linear regression analysis is carried out in the manner modified and adopted by Royce (1964) and Rao (1975). The overall mean of standard length in the present study is 11.45 cm (table 3), which is used for the calculation of one standard deviation ($S_{y.x}$)* and two standard errors of the mean ($2S_{y.x}$)**. The results are arranged in a geographical sequence (figure 3).

The extent of closeness of the samples to one another and to Visakhapatnam sample was further tested on the basis of distance function (D^2) which takes into account all the characters simultaneously.

4.3 *Calculation of D^2*

The computational procedure for the calculation of distance function (D^2) is according to the method given by Rao (1952 Procedure B 1 in Appendix B, Chapter 8), which was suitably modified later by Rao (1975) taking into account the regression statistics.

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* One standard deviation is calculated as

$$S_{y.x} = \left(\Sigma y^2 - \left(\Sigma xy\right)^2 / \Sigma x^2 / n-2\right)^{1/2}$$

** Two standard errors of the mean are calculated as

$$2S_{y.x} = 2S_{y.x}\left(1/n + x^2/\Sigma x^2\right)^{1/2}$$

where Σx^2, Σy^2 and Σxy are corrected sums of squares and products (Appendix I); n = number of fish in each sample; x^2 is the square of the difference between the sample mean of standard length and the overall mean of standard length.

Table 1. Regression coefficients corresponding to different body dimensions (b_1 ..... b_6) regressing on standard length (X_0)

Locality	Sample Size	Regression coefficients					
		b_1	b_2	b_3	b_4	b_5	b_6
Paradeep	40	0.3393	0.3169	0.1196	0.5048	0.1984	0.3353
Visakhapatnam	40	0.3206	0.2860	0.1008	0.4952	0.1989	0.3057
Kakinada	40	0.3361	0.2835	0.1048	0.5198	0.1791	0.2731
Madras	40	0.3636	0.3305	0.1195	0.4903	0.1712	0.3518
Overall	160	0.3428	0.3079	0.1137	0.5047	0.1862	0.3188
F-values resulting from comparison of regression coefficients †		2.9214**	11.3638*	5.8119*	1.3294**	3.7081**	15.6257**
Error mean square		0.0108	0.0061	0.0019	0.0177	0.0071	0.0120

X_1 = Height of the body; X_2 = Head length; X_3 = Maxilla length; X_4 = Length of dorsal base; X_5 = Length of anal base; X_6 = Pectoral length

† degrees of freedom (3,152); *Significant at 1% level; **Not significant

Table 2. Mean values of the different body dimensions for each locality.

	Sample size	Size range (cm SL)	$\bar{X}_0 \pm$ SD	$\bar{X}_1 \pm$ SD	$\bar{X}_2 \pm$ SD	$\bar{X}_3 \pm$ SD	$\bar{X}_4 \pm$ SD	$\bar{X}_5 \pm$ SD	$\bar{X}_6 \pm$ SD
Paradeep	40	9.2-18.7	11.32 ± 2.35	3.57 ± 0.80	3.35 ± 0.75	1.21 ± 0.28	5.73 ± 1.19	2.01 ± 0.47	3.19 ± 0.79
Visakhapatnam	40	9.7-14.6	11.80 ± 1.11	3.78 ± 0.36	3.45 ± 0.33	1.24 ± 0.12	5.87 ± 0.58	2.09 ± 0.24	3.23 ± 0.35
Kakinada	40	7.4-20.4	10.66 ± 2.06	3.40 ± 0.70	3.14 ± 0.59	1.14 ± 0.22	5.40 ± 1.07	1.92 ± 0.38	2.97 ± 0.57
Madras	40	9.1-17.1	12.03 ± 1.89	3.81 ± 0.70	3.59 ± 0.63	1.30 ± 0.23	6.01 ± 0.94	2.13 ± 0.34	3.55 ± 0.68
Overall	160	7.4-20.4	11.45 ± 1.96	3.64 ± 0.73	3.38 ± 0.61	1.22 ± 0.23	5.75 ± 0.99	2.04 ± 0.37	3.23 ± 0.65

Table 3. Pooled variance-covariance matrix.

	X_0	X_1	X_2	X_3	X_4	X_5	X_6
X_0	3.6489	1.2509	0.4150	1.1635	0.6326	0.5679	0.1337
X_1		1.1238	1.8419	0.4400	0.2316	0.2088	0.9475
X_2			0.6795	0.3904	0.4035	0.3641	0.3462
X_3				0.1437	0.3625	0.0493	0.5880
X_4					0.1295	0.2099	0.1340
X_5						0.0771	0.2168
X_6							0.3863

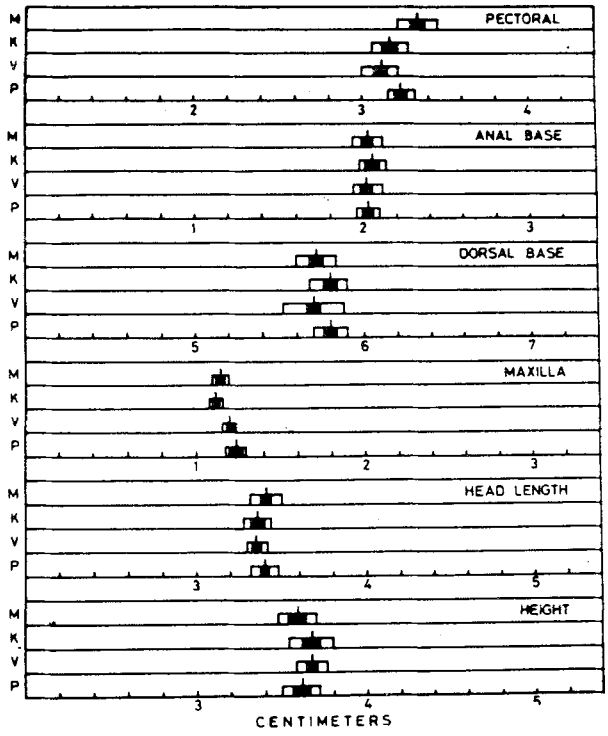

Figure 3. Mean lengths of body dimensions of *Nemipterus japonicus*. The centre line indicates the mean, the hollow bar ± one standard deviation and the solid bar ± two standard errors of the mean as computed from regression statistics. P—Paradeep; V=Visakhapatnam; K—Kakinada; M—Madras.

Table 4. b_{ij} values.

	X_0	X_1	X_2	X_3	X_4	X_5	X_6
X_0	3.6489	1.2509	0.4150	1.1635	0.6326	0.5679	0.1337
X_1		0.6950	1.6996	0.0411	0.0147	0.0141	0.9017
X_2			-3.5243	0.1575	0.2955	0.2650	-1.8741
X_3				-0.2227	0.1641	-0.1208	0.4082
X_4					0.1652	0.0443	0.2354
X_5						0.0620	-0.2479
X_6							-0.3692

Table 5. Transformed normalized mean values (y_i s).

Locality	X_0	X_1	X_2	X_3	X_4	X_5	X_6
Paradeep	-0.0697	-0.0352	0.0290	-0.0660	-0.0616	0.0460	0.0897
Visakhapatnam	0.1803	0.0263	-0.0135	-0.2026	0.3227	-0.3356	-0.6739
Kakinada	-0.4126	0.0392	-0.1253	0.3746	-0.8016	0.8076	0.8860
Madras	0.3020	-0.0303	0.1098	0.2379	0.5406	-0.5181	-0.3018

Table 6. Values of D^2 arranged in increasing order of magnitude. F values with 6,73 degrees of freedom are given in parenthesis.

Paradeep (1)	Visakhapatnam (2)	Kakinada (3)	Madras (4)
(4) 0.9329 (2.91)	(4) 0.2389	(1) 1.8863 (5.88)*	(2) 0.2389 (0.75)
(2) 0.9540 (2.98)	(1) 0.9540	(2) 5.3499 (16.69)*	(1) 0.9329
(3) 1.8863	(3) 5.3499	(4) 5.4050 (16.86)*	(3) 5.4050

*Significant at 1% probability level.

Using the notation of Rao (1952) and Rao (1975), the normalized mean values $x_1 \ldots\ldots x_p$ were transformed to values of $y_1 \ldots\ldots y_p$, which have unit standard deviation. The values of y were obtained through the formulae given below† following the procedure given by Rao (1975). The final D^2 values corresponding to any two groups is the sum of squares of differences in transformed normalized mean values of all characters (excluding X_0). The results are presented in tables 3 to 6.

5. Results

5.1 *Analysis of covariance*

Though the regression coefficients for the different samples are numerically close to one another the F-values comparing the coefficients are significant at 1% level for three characters, namely head length, maxilla length and pectoral length (table 1).

5.2 *Character by character comparison*

The overlap of the solid bars (two standard errors) indicates the closeness of different locality-samples with regard to each character (figure 3). The overlapping was very

†The values of y were obtained through the formulae

$$y_i = x_i - \sum_{j=1}^{i-1} (b_{ij}/(b_{jj})^{(1/2)} y_j/(b_{ii})^{1/2} \text{ for } i = 0, 1 \ldots 6$$

where $b_{11} = \lambda_{11}$

$$b_{ij} = \lambda_{ij} - \sum_{t=1}^{j-1} b_{jt}\, b_{it}/b_{tt} \qquad \text{when } i > j$$

$$\text{and } b_{jj} = \lambda_{jj} - \sum_{t=1}^{j-1} b_{jt}^2/b_{tt} \text{ and } b_{ij} = b_{ji}$$

The formulae given above are obtained on substituting the values of a_{ij} (Rao 1952).

Appendix 1. Corrected sums of squares and products of different body dimensions for four localities

	X_0	X_1	X_2	X_3	X_4	X_5	X_6
Paradeep (n = 40)							
X_0	215.59	73.17	68.34	25.79	108.83	42.78	72.29
X_1		25.25	23.37	8.83	37.04	14.49	24.63
X_2			21.88	8.24	34.61	13.59	22.99
X_3				3.17	13.10	5.13	8.70
X_4					55.27	21.71	36.59
X_5						8.66	14.33
X_6							24.58
Visakhapatnam (n = 40)							
X_0	48.71	15.62	13.94	4.91	24.13	9.69	14.89
X_1		5.28	4.57	1.59	7.95	3.14	4.92
X_2			4.14	1.43	7.08	2.81	4.36
X_3				0.56	2.48	0.95	1.50
X_4					13.22	4.88	7.52
X_5						2.30	3.11
X_6							5.02
Kakinada (n = 40)							
X_0	164.93	55.44	46.76	17.30	85.73	29.54	45.06
X_1		19.14	15.94	5.85	28.83	9.89	15.31
X_2			13.53	4.97	24.30	8.32	12.95
X_3				1.88	9.01	3.09	4.78
X_4					45.11	15.46	23.44
X_5						5.54	8.02
X_6							12.76
Madras (n = 40)							
X_0	139.99	50.91	46.27	16.73	68.64	23.98	49.26
X_1		18.97	17.02	6.15	24.86	8.61	18.09
X_2			15.59	5.56	22.61	7.85	16.49
X_3				2.08	8.16	2.86	5.88
X_4					34.21	11.96	24.17
X_5						4.41	8.35
X_6							17.90

high with regard to head length and anal base at all the localities. The overlap of the solid bars is 100% for height of the body between distantly situated Paradeep and Madras samples as well as between samples from Visakhapatnam and Kakinada which are geographically close to each other. With regard to maxilla, apart from Madras, there is an increasing trend from south to north (Kakinada to Paradeep). Similarly for pectoral length also, barring the Paradeep sample, there is an increasing trend from north to south (Visakhapatnam to Madras). In dorsal base, Paradeep and Kakinada samples showed extreme overlap and there is considerable overlap between Visakhapatnam and Madras also.

Character by character comparison of the samples of different localities may be summarized as follows: (i) greater heights of Visakhapatnam and Kakinada samples compared to other samples (ii) longer heads of Paradeep and Madras samples compared to other samples (iii) longer maxillae of Paradeep and Visakhapatnam samples (iv) longer dorsal bases of Paradeep and Kakinada samples (v) longer pectoral of Madras sample.

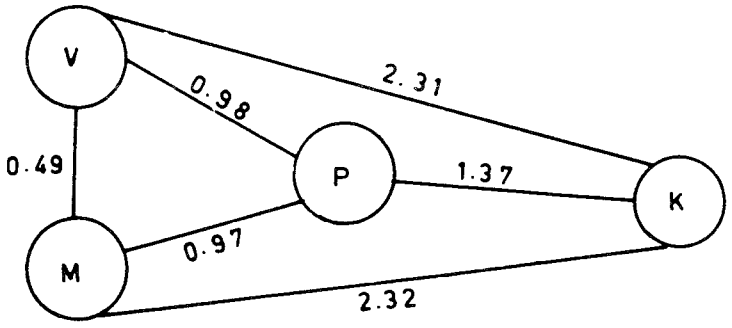

Figure 4. Clusters of locality groups of *Nemipterus japonicus* according to standard lengths and their relationships. P — Paradeep; V — Visakhapatnam; K — Kakinada; M — Madras.

But for the aberrant deviations from a trend line in either Kakinada sample or Paradeep sample or both, there is clinal gradation which is most clearly seen in pectoral and maxillary lengths. The Kakinada and Paradeep samples showed a great degree of overlap of anal base, dorsal base and head length, but the two samples were also found to show no overlap with regard to maxillary length. This shows that the physico-chemical similarity due to freshwater discharge into the sea at Kakinada and Paradeep is probably responsible for the high degree of overlap with regard to anal base and dorsal base while the maxillary length which showed clinal gradation is not influenced in the same manner.

5.3 D^2 *analysis*

The D^2 values were arranged in an increasing order corresponding to each locality (table 6). Figure 4 shows that Visakhapatnam and Madras samples are very close to each other and are probably from the same population. Kakinada sample is the farthest removed from the other three locality-samples. Kakinada sample is almost at equal distance from Visakhapatnam (5.35) and Madras (5.4) samples, but is somewhat nearer to Paradeep sample (1.89). Paradeep sample, which is between the Visakhapatnam-Madras complex on the one hand and Kakinada sample on the other, is a little nearer the former (0.95 with Visakhapatnam and 0.93 with Madras) than the latter (1.89). The relationships thus show that Kakinada sample is the farthest removed and remains distinct from the Paradeep sample also, which occupies an intermediate position between the Visakhapatnam-Madras complex and Kakinada.

6. Discussion

Since all the samples from different localities were collected within an interval of 50 days (January and February 1980), some amount of homogeneity can be assumed at each locality as the specimens belong to the same size group (table 2). Kakinada is geographically near Visakhapatnam (145 km). Paradeep and Madras are respectively 455 and 630 km away from Visakhapatnam. So, there is greater scope of intermingling of populations between Visakhapatnam and Kakinada than between Visakhapatnam and Paradeep or between Visakhapatnam and Madras.

Analysis of covariance gave values significant at 1% probability level for head length, maxilla and pectoral length. Character-by-character comparison revealed that the observed differences between samples from different localities were not so high as

to consider that independent populations exist at the localities. However, taking the overlapping of the two standard errors of the mean as the basis for comparison, a certain degree of similarity is observed between the Visakhapatnam and Madras samples with regard to head length, dorsal and anal bases. Visakhapatnam sample also showed some proximity in head length and anal base with Paradeep and Kakinada samples. On the other hand, Paradeep and Kakinada samples showed some closeness in head length, dorsal and anal bases and to a little extent in pectoral also.

Using all the characters simultaneously, as in D^2 statistic, the degree of closeness or distance of the samples from one another is judged. The statistic (D^2) is significant when Kakinada sample is compared with samples from other localities (table 6). In spite of the greater scope for intermingling of populations off Visakhapatnam and Kakinada, which are geographically closer, the D^2 value of Kakinada with Visakhapatnam is comparatively high (5.35). The D^2 Value of Kakinada with Madras, which are geographically distant, is also of the same magnitude (5.4). Instances of geographically closer localities having higher D^2 values were encountered by Pillay *et al* (1963), Royce (1964) and Rao (1975).

Since geographically close samples are as distinct with regard to D^2 statistic as geographically well-separated samples, it may be inferred that the observed morphological differences are not due to latitudinal differences. The closeness of the Madras and Visakhapatnam samples may be attributed to the fact that these were caught from areas without freshwater influx. Compared to these two places, Kakinada and Paradeep are different in being situated at the mouths of perennial rivers and out of these two, Kakinada receives greater inflow of freshwater from the adjoining river systems (Rama Sarma 1965). Lower salinities at Kakinada and Paradeep seem to affect the morphometrics of *N. japonicus*. The lower the salinity, as at Kakinada, the greater the influence. This phenomenon was also observed by Rao (1975) in *Scomberomorus guttatus*. Hence the intermediateness of Paradeep sample between Kakinada and Visakhapatnam-Madras complex, which strongly indicates that the observed morphological differences are of phenotypic origin rather than genotypic. But for the phenotypic differences, all the *Nemipterus japonicus* populations on the east coast of India appear to belong to a single genetic population, with restricted and localized movements, showing morphological differences under the influence of local physico-chemical conditions.

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References

Hsu C —C and Liu H —C 1977 The comparisons of external morphometric characters of golden thread, *Nemipterus virgatus* (Hottuyn) from the East and South China seas; *J. Fish. Soc. Taiwan* **6** 12-22

Hubbs C L and Hubbs C 1953 An improved graphical analysis and comparison of series of samples; *Syst. Zool.* **2** 49-56

Nammalwar P 1973 A short note on the biometry of *Nemipterus japonicus* (Bloch) in relation to sex in Porto Novo waters; *Sci. Cult.* **39** 349-350

Pillay T V R, Pillay S R and Ghosh K K 1963 A comparative study of the Hilsa, *Hilsa ilisha* (Hamilton) in the Indian waters; *Indo-Pacific Fisheries Council Proceedings*, 10th Session, Seoul, Republic of Korea, Oct 1962, Section II, 62-104

Rama Sarma D V 1965 *Hydrography of the Godavari estuary* Ph.D. thesis, Andhra University, Waltair, pp. 171

Rao C R 1952 *Advanced statistical methods in biometric research,* (New York: John Wiley) pp. 390

Rao D Manikyala 1981 Studies on the biology and biometry of the threadfin bream *Nemipterus japonicus* (Bloch), with observations on the nemipterid fishery off Visakhapatnam (Bay of Bengal); Ph.D. thesis, Andhra University, Waltair pp. 224

Rao K Srinivasa 1975 Biometric comparison of the spotted seer, *Scomberomorus guttatus* (Bloch & Schneider) from five localities along the Indian coast; *Matsya* **1** 63-78

Royce W F 1964 A morphometric study of yellowfin tuna *Thunnus albacares* (Bonnaterre); *Fish Bull., U S Fish and Wildl. Serv.* **63** 395-443

Selva Kumar R A 1971 Notes on biometric features of *Nemipterus japonicus* (Bloch); *J. Bombay Nat. Hist. Soc.* **68** 467-473